An ecological systems approach to examining risk factors for early childhood overweight: findings from the UK Millennium Cohort Study

Short title: Risk factors for early childhood overweight

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ABSTRACT

Objective: To use an ecological systems approach to examine individual-, family-, community-, and area-level risk factors for overweight (including obesity) in 3-year-old children.

Design: Prospective nationally representative cohort study

Setting: England, Wales, Scotland, Northern Ireland

Participants: 13 188 singleton children age three in the Millennium Cohort Study, born between 2000 and 2002, who had complete height/weight data

Main outcome measure: Childhood overweight (including obesity) defined by the International Obesity TaskForce cut-offs for body mass index

Results: 23.0% of 3-year-old children were overweight or obese. In the fully adjusted model, primarily individual- and family-level factors were associated with early childhood overweight: birthweight z-score (adjusted odds ratio, 1.36, 95% CI 1.30 to 1.42), Black ethnicity (1.41, 1.11 to 1.80) (compared to white), introduction to solid foods <4 months (1.12, 1.02 to 1.23), lone motherhood (1.32, 1.15 to 1.51), smoking during pregnancy (1-9 cigarettes daily: 1.34, 1.17 to 1.54; 10-19: 1.49, 1.26 to 1.75; 20+: 1.34, 1.05 to 1.70), parental overweight (both: 1.89, 1.63 to 2.19; father only: 1.45, 1.28 to 1.63; mother only: 1.37, 1.18 to 1.58), prepregnancy overweight (1.28, 1.14 to 1.45), and maternal employment ≥21 hours/week (1.23, 1.10 to 1.37) (compared to never worked). Breastfeeding ≥4 months (0.86, 0.76 to 0.97) (compared to none) and Indian ethnicity (0.63, 0.42 to 0.94) were associated with a decreased risk of early childhood overweight. Children from Wales were also more likely to be overweight than children from England.

Conclusions: Most risk factors for early childhood overweight are modifiable or would allow at-risk groups to be identified. Policies and interventions should focus on parents and providing them with an environment to support healthy behaviours for themselves and their children.

Nearly one quarter of children from resource-rich countries are already overweight or obese by age five,[1-3] suggesting that preventing obesity needs to begin in early life. However, there is little evidence on how to prevent obesity in preschool children,[4-6] so identification of modifiable risk factors is essential to inform the development of effective interventions.[7]

Researchers and policy makers have advocated for an ecological systems approach to addressing obesity rather than focusing on risk factors in isolation.[8-10] In this approach, obesity is conceptualised as being influenced by factors across multiple levels: individual and family risk factors as well as characteristics of the community and region. The UK Government Office for Science published the Foresight Tackling Obesities report with a systems map illustrating the determinants of obesity across these levels and their interrelations.[9] However, few studies have the breadth and depth of information to investigate the relationships between obesity and individual-, family-, community-, and area-level factors. Furthermore, to our knowledge, this approach has not been used to examine obesity in young children.

The Millennium Cohort Study (MCS) is a nationally representative, contemporary cohort of British children followed since infancy and provides an opportunity to simultaneously assess risk factors for early childhood overweight using an ecological systems approach. Data from this ethnically and socioeconomically diverse cohort were used to examine individual-, family-, community-, and area-level risk factors for overweight (including obesity) in children age three.

METHODS

Participants

The MCS is a prospective study of UK children born in the new millennium. Families were invited to participate if they were eligible for Child Benefit (a universal benefit for families with children) and resident in England, Wales, Scotland, and Northern Ireland when the child was aged nine months.[11] The MCS employed a stratified clustered sampling design to over-represent children living in disadvantaged areas and from ethnic minority groups. Additional information on the sampling framework has been previously reported.[12] The original sample consisted of 18 819 children (18 553 families), born between September 2000 and January 2002, with a mean age of 9.2

months (SD 0.5) at the first contact (response 72%). Eighty percent (14 630/18 296) of the singleton infants participated in the second contact, which took place between September 2003 and January 2005, when the children were mean age 37.7 months (SD 2.5). Attrition was highest among families from Northern Ireland, in electoral wards in England defined as 'ethnic' (based on the 1991 Census, if at least 30% of residents were from an ethnic minority group), and 'disadvantaged' wards from all UK countries (above the upper quartile of the Child Poverty Index).[13] At both contacts, main respondents (over 99% were natural mothers) and their partners (of those interviewed, over 99% were natural fathers) were interviewed in the home. Data were obtained from the UK Data Archive, University of Essex. The MCS received ethical approval from the South West and London Multi-Centre Research Ethics Committees for the first and second contacts, respectively.[14]

Among the 14 630 singleton children, 13 188 had data available for analysis. Families were excluded if the main respondent was not female (185), the partner respondent was not male (132), there were two singleton cohort children from the same family (10), or the child had a missing height or weight (802) or a height-for-age, weight-for-age, or body mass index (BMI; weight/height^2) -for-age z-score $\leq$ -5 or $\geq$ 5 (467). Some participants satisfied more than one exclusion criterion. Children were more likely to have missing or implausible BMI data if they were from an ethnic minority group, lower income family, or if their mother was a lone parent, had a lower academic qualification, or lower socioeconomic circumstances ($p<.01$).

Outcome measure

At the second contact, trained interviewers measured the children's weight and height without shoes or outdoor clothing. The children were weighed using Tanita HD-305 scales (Tanita UK Ltd, Middlesex, UK), recorded to the nearest 0.1 kg, and height was measured using Leicester Height Measure Stadiometers (Seca Ltd, Birmingham, UK), recorded to the nearest 0.1 cm. Childhood overweight (including obesity) was defined by the International Obesity TaskForce cut-offs for BMI, which are age and sex specific.[15]

Potential risk factors

Potential risk factors were chosen based on prior evidence,[10, 16-19] including previous research on early childhood obesity in the MCS. Overall, 26 risk factors were examined across the following levels (Table 1): individual (6), family (13), community (5), area (2). All individual-, family-, and community-level risk factors were reported by parents, usually the mother. Area-level risk factors were derived from the child's address at the first contact. Definitions of risk factors are presented in Table 1, while more detailed descriptions are published elsewhere.[17-19] Only those factors not previously defined are described here. Birthweight z-scores were calculated using the British 1990 growth reference[20], which are adjusted for gestational age and gender. Parental height and weight at the first contact was collected by self-report. Children were grouped as having neither parent overweight (BMI <25 kg/m^2) or their father, mother, or both parents overweight (BMI ≥25 kg/m^2). At the first contact, mothers were asked their smoking habits immediately before pregnancy, whether they changed during pregnancy, and if so, the month they changed. Maternal smoking during pregnancy was defined as the number of cigarettes smoked daily at three months gestation. Mothers also reported whether the cohort child was their first live born or not (parity). Ward type was based on the grouping of electoral wards (as established in 1998) as defined for the MCS sampling framework. Wards that were not 'ethnic' or 'disadvantaged' (previously defined) were considered 'advantaged'. In Wales, Scotland, and Northern Ireland there was no 'ethnic' stratum.[12]

Table 1. Potential risk factors, sweep of data collection, and factor level of analysis

Variable	Sweep of data collection*	Units of analysis
Individual		
Birthweight	First	z-score adjusted for gestational age and gender
Child's gender	First	Male or female
Child's ethnicity	First	White; Mixed; Indian; Pakistani; Bangladeshi; Black; Other
Breastfeeding duration	First	Never breastfed; breastfed for <17.4 weeks; breastfed for ≥17.4 weeks
Introduction of solid foods	First	Weeks: <17.4 or ≥17.4
Television viewing	Second	Daily hours: <1; ≥1 & <3; ≥3
Family		
Maternal socioeconomic circumstances	First	Managerial & professional; intermediate; small employers & own account; lower supervisory & technical; semi-routine & routine; never worked & long-term unemployed

Maternal highest academic qualification	First	Degree (highest); diploma in higher education; A/AS/S levels; O level/GCSE grades A-C; GCSE grades D-G; other; none (lowest)
Lone motherhood status	First	Non-lone mother or lone mother
Age at first live birth	First	Years: 14-19; 20-24; 25-29; 30-34; 35+
Age at MCS birth	First	Years: 14-19; 20-24; 25-29; 30-34; 35+
Parity	First	Cohort child first live born (nulliparous) or not first live born (multiparous)
Number of children in the household (including cohort child)	Second	1; 2 or 3; 4 or more
Household income	Second†	Per annum: £0-11000; £11000-22000; £22000-33000; £33000+
Maternal smoking during pregnancy (at 3 months gestation)	First	Daily: none, 1-9, 10-19, 20+
Parental overweight when cohort child was aged 9 months	First	BMI (kg/m^2): Both parents <25; mother only ≥25; father only ≥25; both parents ≥25
Maternal prepregnancy overweight	First	Yes (BMI ≥25 kg/m^2) or no (BMI <25 kg/m^2)
Maternal employment‡	First & second	Hours worked per week: never worked; 1-20; 21+
Whether child has meals at regular times	Second	Always, usually, never or sometimes
Community		
Easy access to food shops and supermarkets	First	How common: very, fairly, not very, not at all
Neighbourhood conditions-noisy neighbours, rubbish, vandalism, pollution§	First	How common: very, fairly, not very, not at all
Satisfaction with area where family lives	First	Very satisfied, fairly satisfied, neither satisfied nor dissatisfied, fairly dissatisfied, very dissatisfied
Whether there are any places where children can play safely	First	Yes or no
Access to a garden	First	Yes or no
Area		
Country	First	England, Wales, Scotland, Northern Ireland
Ward type	First	Advantaged, disadvantaged, ethnic

* Children were aged approximately 9 months at the first contact and 3 years at the second contact.

† Values from the second contact were used unless missing, values from the first were substituted.

‡ Average hours worked per week during the weeks worked from birth to the second contact.

§ A composite of neighbourhood conditions based on how common the following were: noisy neighbours or loud parties; rubbish or litter lying around; vandalism and deliberate damage to property; pollution, grime or other environmental problems.

Statistical methods

All analyses were conducted using STATA statistical software, version 9.2 SE (Stata Corporation, Texas), with survey commands to account for the clustered sampling

design and obtain robust standard errors. Weighted percentages were derived and regression analyses were conducted using survey and non-response weights to account for the clustered sampling and attrition between contacts. P values were calculated by an adjusted Wald test.

Unadjusted logistic regression analyses were conducted to examine the relationships between individual-, family-, community-, and area-level factors and early childhood overweight (Table 1). Factors significant at the $p \leq .05$ level were included in the adjusted models in a stepped approach. Model 1 included individual-level risk factors only. In Models 2-4, family-, community-, and area-level risk factors were added sequentially. Only one interaction was examined, specified *a priori*, between 'child's gender' and 'which parent overweight'. The interaction was not significant in the unadjusted analyses and not included in the adjusted models.

RESULTS

At age three, 18.0% (2410) of children were overweight and an additional 5.0% (691) were obese. As illustrated in Table 2 (first column), the MCS represents a diverse sample of preschool children in modern Britain. 13% of children were from an ethnic minority group, 14% of mothers were lone parents, and 50% of families had an annual household income of £22000 or less.

Unadjusted analyses

Individual-level

Children were more likely to be overweight if they had a greater birthweight z-score, were Black (compared to white children), introduced to solid foods before four months (compared to after four months), or watched at least one hour of television daily (compared to less than one) (Table 2). Children were less likely to be overweight if they were Indian or Pakistani, or had ever been breastfed (compared to never breastfed). There was no association between early childhood overweight and the child's gender.

Family-level

Children were more likely to be overweight if their mother was a lone parent (compared to non-lone mothers), smoked 1-19 cigarettes daily during pregnancy (compared to none), both parents were overweight or obese, their mother only, or their father only

(compared to neither), their mother was overweight prepregnancy (compared to normal weight), or worked at least twenty-one hours each week (compared to never worked) (Table 2). There was a tendency for children from more advantaged groups (measured by maternal socioeconomic circumstances, education, and household income) to be at lower risk for overweight (p=.1 level). There were no associations between early childhood overweight and maternal age at first live birth or MCS birth, parity, number of children in the household, or whether the child has meals at regular times.

Community-level

Children were more likely to be overweight if their mother reported there was no access to a garden (compared to those who did) (Table 2). There were no consistent patterns between early childhood overweight and access to food shops, neighbourhood conditions, satisfaction with the area, or access to places where children can play safely.

Area-level

Children were more likely to be overweight if their family lived in Wales or Northern Ireland (compared to England) or in a disadvantaged ward (compared to advantaged); however, children were less likely to be overweight if their family lived in an ethnic ward (Table 2).

Table 2. Weighted percentages and unadjusted odds ratios (95% CI) of risk factors for overweight in children age three

		N (Weighted %)	Weighted % Overweight	Unadjusted OR (95% CI)	p value
Individual					
Birthweight z-score				1.36 (1.30 to 1.42)	p<.001
	Missing N	145			
Child's gender					p=.19
	Female	6524 (50)	24	1.07 (0.97 to 1.18)	
	Male	6664 (50)	22	1	
	Missing N	0			
Child's ethnicity					p<.001
	White	11136 (87)	23	1	
	Mixed	359 (3)	23	1.00 (0.74 to 1.34)	
	Indian	337 (2)	10	0.35 (0.25 to 0.50)	
	Pakistani	586 (3)	19	0.75 (0.61 to 0.92)	
	Bangladeshi	205 (0.9)	21	0.89 (0.61 to 1.29)	
	Black	376 (3)	30	1.40 (1.06 to 1.84)	
	Other ethnic group	162 (1)	20	0.84 (0.50 to 1.43)	
	Missing N	27			
Breastfeeding duration					p<.001
	Never breastfed	4203 (30)	25	1	

	< 4 months	5515 (42)	23	0.88 (0.80 to 0.97)
	≥ 4 months	3454 (28)	20	0.75 (0.66 to 0.85)
	Missing N	16		
Introduction of solid foods				p<.001
	< 4 months	4633 (36)	26	1.25 (1.14 to 1.38)
	≥ 4 months	8544 (64)	22	1
	Missing N	11		
TV viewing (hours daily)				p=.016
	< 1	3055 (23)	21	1
	≥ 1 & < 3	7746 (60)	23	1.14 (1.02 to 1.28)
	≥ 3	2355 (17)	25	1.23 (1.06 to 1.43)
	Missing N	32		
Family				
Maternal socioeconomic circumstances				p=.11
Managerial and professional occupations		3770 (31)	23	0.94 (0.83 to 1.06)
Small employers and own account workers		474 (4)	19	0.74 (0.58 to 0.96)
Intermediate occupations		2298 (18)	21	0.84 (0.73 to 0.97)
Lower supervisory and technical occupations		721 (5)	23	0.94 (0.75 to 1.16)
Semi-routine and routine occupations		4622 (35)	24	1
Never worked and long-term unemployed		1143 (7)	23	0.91 (0.75 to 1.10)
Missing N		160		
Maternal highest academic qualification				p=.15
Degree		2294 (18)	22	0.86 (0.72 to 1.02)
Diploma in higher education		1204 (9)	23	0.91 (0.75 to 1.11)
A/AS/S levels		1283 (10)	21	0.79 (0.65 to 0.96)
O levels/GCSE grades A-C		4488 (35)	23	0.92 (0.80 to 1.05)
GCSE grades D-G		1358 (11)	26	1.06 (0.89 to 1.28)
Other academic qualifications		324 (2)	22	0.89 (0.61 to 1.29)
None of these qualifications		2210 (15)	25	1
Missing N		27		
Lone motherhood status				p=.007
Lone mother		1971 (14)	26	1.21 (1.05 to 1.39)
Non-lone mother		11217 (86)	23	1
Missing N		0		
Age at first live birth (years)				p=.070
14-19		2406 (18)	23	1.02 (0.89 to 1.17)
20-24		3481 (25)	24	1.08 (0.94 to 1.24)
25-29		3750 (30)	23	1
30-34		2453 (20)	21	0.88 (0.76 to 1.02)
35+		725 (6)	23	1.01 (0.81 to 1.26)
Missing N		373		
Age at MCS birth (years)				p=.70
14-19		984 (8)	23	0.96 (0.80 to 1.16)
20-24		2298 (16)	23	0.95 (0.82 to 1.10)
25-29		3662 (28)	24	1
30-34		4038 (31)	22	0.92 (0.81 to 1.03)
35+		2197 (17)	23	0.98 (0.86 to 1.12)
Missing N		9		
Parity				p=.32
First live birth		5437 (42)	23	0.95 (0.86 to 1.05)
Not first live birth		7608 (58)	23	1
Missing N		143		
Number of children in the household				p=.50
1		3275 (25)	23	1
2 or 3		8519 (66)	23	1.02 (0.91 to 1.13)
4 or more		1363 (9)	24	1.10 (0.93 to 1.30)
Missing N		31		
Household income				p=.11
£0-11000 per annum		3055 (22)	24	1.18 (1.01 to 1.37)
£11000-22000 per annum		3871 (28)	24	1.18 (1.02 to 1.36)
£22000-33000 per annum		2791 (23)	24	1.17 (1.00 to 1.36)
£33000+ per annum		3164 (27)	21	1

Missing N	307			
Smoking during pregnancy (daily)				
None	10130 (77)	22	1	p=.009
1-9	1558 (12)	25	1.17 (1.00 to 1.36)	
10-19	975 (7)	28	1.34 (1.11 to 1.61)	
20+	470 (4)	24	1.12 (0.85 to 1.47)	
Missing N	55			
Parental overweight				p<.001
Both	2343 (18)	32	2.26 (1.96 to 2.59)	
Mother only	2450 (19)	27	1.78 (1.54 to 2.05)	
Father only	3302 (27)	21	1.31 (1.14 to 1.50)	
Neither	4674 (37)	17	1	
Missing N	419			
Maternal prepregnancy overweight				p<.001
Yes	3625 (28)	31	1.83 (1.66 to 2.02)	
No	8772 (72)	20	1	
Missing N	791			
Maternal hours worked per week				p=.024
Never worked	5484 (41)	22	1	
1-20 hours	3463 (28)	22	0.98 (0.88 to 1.09)	
21+ hours	4183 (31)	25	1.15 (1.02 to 1.29)	
Missing N	58			
Whether child has meals at regular times				p=.43
Always	6261 (47)	23	1	
Usually	5669 (44)	24	1.05 (0.95 to 1.16)	
Never or sometimes	1226 (8)	22	0.97 (0.82 to 1.14)	
Missing N	32			
Community				
Easy access to food shops and supermarkets				p=.29
Very common	7234 (56)	23	1	
Fairly common	3971 (30)	23	1.01 (0.91 to 1.12)	
Not very common	1221 (9)	26	1.19 (0.99 to 1.42)	
Not at all common	736 (5)	24	1.08 (0.88 to 1.32)	
Missing N	26			
Neighbourhood conditions – noisy neighbours to rubbish, vandalism, pollution				p=.17
Very common	862 (6)	22	0.96 (0.79 to 1.17)	
Fairly common	2212 (16)	25	1.15 (1.00 to 1.32)	
Not very common	5060 (39)	23	1.00 (0.90 to 1.11)	
Not at all common	5032 (39)	23	1	
Missing N	22			
Satisfaction with area where family lives				p=.10
Very satisfied	5587 (44)	22	1	
Fairly satisfied	5197 (38)	24	1.10 (0.99 to 1.21)	
Neither satisfied nor dissatisfied	964 (7)	26	1.27 (1.05 to 1.53)	
Fairly dissatisfied	916 (6)	23	1.09 (0.90 to 1.32)	
Very dissatisfied	500 (4)	22	1.02 (0.79 to 1.31)	
Missing N	24			
Whether there are any places where children can play safely				p=.22
Yes	8078 (65)	23	1	
No	4926 (35)	24	1.07 (0.96 to 1.18)	
Missing N	184			
Access to a garden				p=.015
Yes	11899 (90)	23	1	
No	1272 (10)	27	1.24 (1.04 to 1.48)	
Missing N	17			
Area				
Country				p<.001
England	8272 (58)	23	1	
Wales	2010 (16)	27	1.26 (1.11 to 1.44)	
Scotland	1616 (13)	24	1.08 (0.93 to 1.24)	

	Northern Ireland	1290 (12)	27	1.28 (1.13 to 1.46)	
	Missing N	0			
Ward type					p<.001
	Advantaged	5562 (60)	22	1	
	Disadvantaged	6117 (35)	25	1.13 (1.02, 1.26)	
	Ethnic	1509 (5)	20	0.85 (0.76, 0.95)	
	Missing N	0			

OR, odds ratio; CI, confidence interval

Adjusted analyses

Results from the stepped analysis are presented in Table 3. After mutual adjustment for individual-level factors (Model 1), early childhood overweight was directly associated with birthweight, Black ethnicity, early introduction of solid foods, and television use for at least three hours daily. Protective factors for early childhood overweight were Indian ethnicity and breastfeeding. All relationships, except television viewing, were maintained after adjustment for family- (Model 2), community- (Model 3), and area-level (Model 4) factors.

After mutual adjustment for individual- and family-level factors (Model 2), early childhood overweight was directly associated with lone motherhood, smoking during pregnancy (1-19 cigarettes daily), parental overweight, prepregnancy overweight, and maternal employment (21+ hours/week). These relationships were maintained after adjustment for community- (Model 3) and area-level (Model 4) factors.

The relationship between early childhood overweight and access to a garden was not maintained after it was added in Model 3 or after adjustment for area-level factors (Model 4). After area-level factors were added in Model 4, early childhood overweight was only associated with residence in Wales.

Forward and backward stepwise logistic regression analyses were conducted to check the validity of the model from the stepped analysis. All significant factors from the fully adjusted stepped model were retained in the final forward and backward models, demonstrating agreement between the three approaches (data not shown).

Table 3. Adjusted odds ratios (95% CI) of risk factors for overweight in children age three

	Model 1: Adjusted for all individual factors	Model 2: + Adjusted for all family factors	Model 3: + Adjusted for all community factors	Model 4: + Adjusted for all area factors
Individual				
Birthweight z-score	1.36 (1.30 to 1.43)*	1.35 (1.28 to 1.42)*	1.35 (1.29 to 1.42)*	1.36 (1.30 to 1.42)*
Child's ethnicity				
White	1	1	1	1
Mixed	1.16 (0.86 to 1.57)	1.05 (0.78 to 1.42)	1.04 (0.77 to 1.40)	1.18 (0.90 to 1.53)
Indian	0.46 (0.32 to 0.65)*	0.49 (0.33 to 0.73)*	0.49 (0.33 to 0.73)*	0.63 (0.42 to 0.94)*
Pakistani	0.94 (0.77 to 1.14)	0.98 (0.78 to 1.22)	0.98 (0.78 to 1.23)	1.01 (0.81 to 1.26)
Bangladeshi	1.13 (0.76 to 1.68)	1.03 (0.61 to 1.75)	1.01 (0.60 to 1.70)	1.04 (0.67 to 1.60)
Black	1.61 (1.25 to 2.07)*	1.35 (1.08 to 1.69)*	1.29 (1.03 to 1.61)*	1.41 (1.11 to 1.80)*
Other ethnic group	1.03 (0.61 to 1.74)	1.15 (0.66 to 2.02)	1.12 (0.65 to 1.93)	0.75 (0.44 to 1.30)
Breastfeeding duration				
Never breastfed	1	1	1	1
< 4 months	0.87 (0.79 to 0.96)*	0.90 (0.81 to 1.00)*	0.90 (0.81 to 1.00)*	0.92 (0.83 to 1.00)*
≥ 4 months	0.73 (0.64 to 0.84)*	0.84 (0.73 to 0.97)*	0.84 (0.74 to 0.97)*	0.86 (0.76 to 0.97)*
Introduction of solid foods				
< 4 months	1.18 (1.07 to 1.31)*	1.11 (1.00 to 1.23)*	1.11 (1.01 to 1.23)*	1.12 (1.02 to 1.23)*
≥ 4 months	1	1	1	1
TV viewing (hours daily)				
< 1	1	1	1	1
≥ 1 & < 3	1.11 (0.99 to 1.25)	1.08 (0.96 to 1.22)	1.08 (0.95 to 1.22)	1.07 (0.97 to 1.19)
≥ 3	1.17 (1.00 to 1.36)*	1.07 (0.91 to 1.27)	1.07 (0.90 to 1.26)	1.08 (0.95 to 1.23)
Family				
Lone motherhood status				
Lone mother		1.49 (1.26 to 1.78)*	1.47 (1.24 to 1.76)*	1.32 (1.15 to 1.51)*
Non-lone mother		1	1	1
Smoking during pregnancy (daily)				
None		1	1	1
1-9		1.26 (1.07 to 1.50)*	1.25 (1.06 to 1.49)*	1.34 (1.17 to 1.54)*
10-19		1.56 (1.26 to 1.94)*	1.55 (1.25 to 1.92)*	1.49 (1.26 to 1.75)*
20+		1.16 (0.86 to 1.58)	1.16 (0.85 to 1.57)	1.34 (1.05 to 1.70)*
Parental overweight				
Both		2.01 (1.69 to 2.39)*	2.02 (1.70 to 2.40)*	1.89 (1.63 to 2.19)*
Mother only		1.40 (1.18 to 1.66)*	1.40 (1.18 to 1.66)*	1.37 (1.18 to 1.58)*
Father only		1.41 (1.22 to 1.63)*	1.42 (1.23 to 1.64)*	1.45 (1.28 to 1.63)*
Neither		1	1	1
Maternal prepregnancy overweight				
Yes		1.27 (1.11 to 1.45)*	1.27 (1.11 to 1.45)*	1.28 (1.14 to 1.45)*
No		1	1	1
Maternal hours worked per week				
Never worked		1	1	1
1-20 hours		1.08 (0.95 to 1.22)	1.08 (0.95 to 1.23)	1.10 (0.99 to 1.23)
21+ hours		1.26 (1.10 to 1.45)*	1.27 (1.11 to 1.46)*	1.23 (1.10 to 1.37)*
Community				
Access to a garden				
Yes			1	1
No			1.18 (0.98 to 1.42)	1.15 (0.99 to 1.34)
Area				
Country				
England				1
Wales				1.15 (1.01 to 1.31)*
Scotland				1.06 (0.91 to 1.24)
Northern Ireland				1.11 (0.97 to 1.28)

Ward type		
	Advantaged	1
	Disadvantaged	1.00 (0.90, 1.10)
	Ethnic	0.98 (0.80, 1.19)

OR, odds ratio; CI, confidence interval

*p≤.05

DISCUSSION

Among a nationally representative cohort of contemporary British preschool children, 23% were overweight or obese at age three. We found that primarily individual- and family-level risk factors were associated with early childhood overweight, including birthweight, Black ethnicity, early introduction of solid foods, lone motherhood, smoking during pregnancy, parental overweight, prepregnancy overweight, and maternal employment of 21+ hours/week. Protective factors for early childhood overweight were Indian ethnicity and breastfeeding for at least four months. Although there was limited evidence for relationships between community-level factors and early childhood overweight, children from Wales were more likely to be overweight than children from England.

The MCS provided the breadth and depth of social and health information on children, their families, and their environment to simultaneously examine risk factors for early childhood overweight across multiple levels. The MCS is longitudinal so we have been able to examine the cumulative influence of risk factors, such as infant feeding practices or maternal employment patterns, on later overweight. Since some factors are likely to be on the causal pathway in the development of overweight, Buchan and colleagues suggest that unadjusted relationships should not be disregarded even if adjusted relationships are no longer significant.[7] A stepped analysis has allowed us to examine the impact of sequential adjustment on risk factors at each level, reflecting an ecological systems approach to addressing early childhood overweight. Few studies have used this approach. Although the forward and backward stepwise regression models identified the same risk factors as by the ecological systems approach, they would not have revealed factors that lost significance after adjustment--potentially missing modifiable risk factors on the causal pathway.[7]

There are limitations to the MCS data. No measures of body composition were collected in the MCS and BMI cannot discriminate between lean and fat mass. Although BMI is a reasonable proxy for body fatness at a population level, particularly at the higher end of the distribution,[21] it is less reliable when comparing children from different ethnic groups.[21,22] Although information was collected on the children's television viewing habits at age three, little else is known about their physical activity and dietary patterns. Furthermore, some observations, such as television viewing, have been only collected at one time point, so the temporality of the associations cannot be determined. These factors can be re-examined at subsequent sweeps when the MCS children are school-age. The questions about community-level factors were not developed for research on childhood obesity. There may be limitations with the questions themselves or mothers' interpretation of the questions. At the first contact, mothers were asked about health behaviours during pregnancy and early postpartum. Recall bias may have influenced the information collected. Although tobacco consumption during pregnancy is often under-reported[23], recall of breastfeeding practices has been found to be reliable and valid[24]. Since we found that smoking during pregnancy increased the risk of early childhood overweight, under-reporting of smoking is likely to under-estimate the strength of the association. At both contacts, parents reported their height and weight. Although research suggests that misreporting of height and weight could lead to underestimations of obesity prevalence[25], estimates of parental overweight (including obesity) in the MCS are similar to those reported in a national survey of adults in England[26]. Any misreporting of height and weight is likely to under-estimate the strength of the association between parental body size and early childhood overweight.

A review of policy-relevant risk factors for early childhood overweight identified individual-, family-, and community-level factors, but found that few studies examined risk factors across multiple levels.[16] The individual- and family-level risk factors we identified are consistent with the published literature on early childhood overweight[16] as well as on risk factors for overweight in older children[10]. Previous studies have also reported that an increasing birthweight is associated with overweight in young children and across the lifecourse.[10, 27, 28] There has been limited research on ethnic differences in overweight among British children, particularly young children. At age three, we found that Black children were more likely to be overweight than white children, while South Asian children were less likely. However, research has shown that

South Asian children exhibit greater insulin resistance, a precursor to cardiovascular disease, at similar adiposity levels of white children.[29] Deurenberg and colleagues have found that for the same BMI children from different ethnic groups have dissimilar percentages of body fat.[22] This suggests that ethnic variation in overweight (including obesity) may not represent true differences in body composition.

There is evidence that breastfeeding protects against overweight across the lifecourse,[30] which is consistent with the relationship in the MCS. However, a study by Toschke and colleagues found limited support for an association between breastfeeding and fat mass, except that children breastfed for at least six months had lower total and trunk fat masses in the top decile compared to children never breastfed.[31] While there are less consistent relationships with the introduction of solid foods, [16, 28] we found an increased risk of overweight with early weaning. We also found that high levels of television viewing were associated with overweight, consistent with other studies in young children.[16]

There is evidence for a socioeconomic gradient in childhood overweight, with children from lower socioeconomic circumstances at higher risk.[32] We found some differences by socioeconomic factors in unadjusted analyses, but only lone parenthood was significant in the final model. Our results support prior research that parental overweight increases the risk of overweight in their offspring across the lifecourse.[27, 28] We also found that prepregnancy overweight was associated with early childhood overweight, consistent with other studies,[16] and independent of parental overweight postpartum. There is an increasing body of research that smoking during pregnancy is associated with an increased risk of early childhood overweight.[16, 33] We also found support for a dose-response relationship with cigarette consumption (test for trend in the final model, $p<.001$), which has been previously reported.[16, 33] The relationships with prepregnancy overweight and smoking during pregnancy suggest a possible influence of programming in utero.[33, 34] Maternal hours worked per week was also found to predict early childhood overweight. Support for this relationship has been reported primarily in older children.[35]

Few other studies have examined community-level factors and early childhood overweight.[16] The lack of relationships with community-level factors could be due to

limitations of the data collected; however, other research in preschool children has also found no evidence for relationships between different community-level factors and overweight.[16] In contrast, studies in school-age children have reported associations between community-level factors and overweight,[36] suggesting that the environment may influence weight gain when children are older. Although there is little known about country and regional differences in early childhood overweight, children in the MCS from Wales and Northern Ireland were found to be at higher risk for overweight than children from England. One other study has reported variation in early childhood overweight by state of residence in Australia.[3]

Implications for policy and practice

Our results provide additional evidence that obesity prevention needs to begin in early life. When an ecological systems approach was applied to examining overweight in young children, individual- and family-level risk factors were found to be more influential than community- and area-level factors. Our findings suggest that obesity prevention should focus on supporting parents, particularly in promoting maternal health behaviours during pregnancy and postpartum. There are a limited number of interventions on preventing early childhood obesity and most have targeted dietary, physical activity, and sedentary behaviours during the preschool years.[4-6] Wen and colleagues are conducting a randomised controlled trial of home visits over the first two years of life with the aim of preventing overweight in preschool children.[37] Whilst this novel study addresses gaps in the evidence base, additional interventions focusing on early factors are needed.

Since parental overweight is one of the strongest predictors of early childhood overweight as well as overweight across the life course,[28] supporting parents to maintain a healthy weight is an important component of obesity prevention. The US has a target to reduce the number of overweight adults[38] and addressing adult obesity is a component of the UK Government's obesity strategy.[9, 39] Furthermore, maternal overweight prepregnancy is increasing in the US[40] and UK.[41] The recently published cross-Government obesity strategy for England proposes that obesity prevention will be integrated into routine health visits to identify at-risk families.[39] During the first antenatal visit, health professionals will give advice to overweight

mothers on healthy weight gain during pregnancy. Furthermore, health visits during infancy will focus on promoting a healthy weight in early life.

An ecological systems approach to tackling obesity requires action across government departments. This is well illustrated by action on infant feeding. It has been suggested that improving breastfeeding rates could significantly reduce the number of cases of childhood obesity.[42] There is international support to increase breastfeeding rates,[38, 43] with the aim for mothers to exclusively breastfeed for six months.[44] The WHO Child Growth Standard promotes breastfeeding by monitoring infant growth with a chart developed from exclusively breastfed infants.[45] The cross-Government obesity strategy for England endorses the adoption of the WHO Child Growth Standard as well as an information campaign to promote breastfeeding.[39] Legislation has been proposed in England[46] and enacted elsewhere[47, 48] to protect breastfeeding in public places and/or at work. In the UK, government efforts to increase paid parental leave[49] and promote work/life balance[50] may help support infant feeding recommendations.[44]

Most risk factors for early childhood overweight, including parental overweight and maternal smoking during pregnancy, are modifiable or would allow at-risk groups, such as lone mothers or overweight women early in pregnancy, to be identified. Improving modifiable risk factors could reduce childhood obesity at the population level.[42, 51] Since the short- and long-term consequences of obesity are a significant burden to society,[9] even a small decrease in the prevalence of obesity at the population level is worth achieving. However, modifying health behaviours requires action at many different levels. Policies at the community- and regional-levels can help create an environment that supports healthy behaviours for parents and their children.

What this paper adds

What is already known on this subject?

- Researchers and policy makers advocate for an ecological systems approach to addressing obesity rather than focusing on risk factors in isolation.
- Few studies have the breadth and depth of information to simultaneously examine the relationships between obesity and individual-, family-, community-, and area-level factors, particularly in young children.

What does this study add?

- Primarily individual- and family-level risk factors are associated with early childhood overweight.
- Most risk factors for early childhood overweight are modifiable or would allow at-risk groups to be identified.

Policy implications

- Policies and interventions should focus on parents and providing them with an environment to support healthy behaviours for themselves and their children.

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Competing interests

All authors have no competing interests to declare.

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